REMARKS

By the present amendment, claims 1 to 18 are pending in the application. Claims 1 and 10 are the independent claims.

Restriction Requirement

In response to the restriction requirement, applicants hereby affirm the election, with traverse, of the claims of Group I, i.e., claims 1 to 18, 22 to 30 and 34 to 36, drawn to a silicon carbide single crystal.

In response to the restriction requirement, non-elected method claims 19 to 21 and 31 to 33 have been canceled without prejudice to the filing of a divisional application directed to canceled method claims 19 to 21 and 31 to 33.

Dependent product-by-process claims 22 to 30 and 34 to 36 have also been canceled by the present amendment because they all depend, directly or indirectly, on canceled independent method claim 19 or 31. Dependent product-by-process claims 22 to 30 and 34 to 36 have been canceled without prejudice to the filing of a divisional application directed to the subject matter of claims 22 to 30 and 34 to 36.

§102/§103

Claims 1 to 18 were rejected under 35 U.S.C. §102(b) as being anticipated by Japan No. 11-106297 (the Office Action inadvertently cited JP 1106297).

Claims 1 to 18, 22 to 30 and 34-36 were rejected under 35 U.S.C. §103(a) as being unpatentable over U.S. Patent No. 5,248,385 to Powell in view of Japan No. 11-106297.

These rejections are respectfully traversed.

The Present Invention

An object of the present invention is to solve the problem that conventional methods cannot grow a high quality silicon carbide single crystal with completely no micropipe defects and little stacking defects.

The present invention according to claim 1 is characterized by "comprising: a single crystal growing face inclined at an angle ranging from 3 degrees or more to 60 degrees or less with respect to the (11-20) face to a direction inclined at an angle ranging from -45 degrees or more to 45 degrees or less from a <0001> direction to the [1-100] direction". The present invention according to claim 10 is characterized by "comprising: an epitaxial growing face inclined at an angle ranging from 3 degrees or more to 60 degrees or less with respect to the (11-20) face to a direction inclined at an angle ranging from -45 degrees or more to 45 degrees or less from a <0001> direction to the [1-100] direction". The other claims under the examination include these characteristics.

By providing a structure according to the present inventions, it becomes possible to provide a silicon carbide single crystal with completely no micropipe defects and a significantly smaller amount of stacking defects compared with the conventional single crystal. Therefore, the present inventions are useful for various applications for use in devices using a silicon carbide single crystal.

Patentability

JP11-106297 (JP '297) discloses that when a silicon carbide single crystal is grown, a substrate, in which the plane direction of surface is in the range of $-30° \leqq \alpha \leqq +30°$ of the angle of inclination (α) in the [0001] direction from the {11-20} plane, and in the range of $-10° \leqq \beta \leqq +10°$ of the angle of rotation (β) around the [0001] axis, is used as a seed crystal.

In other words, in cited JP '297, it is disclosed that a seed crystal consisting of a silicon carbide single crystal having a crystal plane exposed in the range of angle within ±30° in the [0001] direction, and within ±10° in the [1-100] direction around (11-20) plane is used. JP '297 also discloses that such a technology makes it possible to perfectly prevent generation of a polycrystal even under a 100% nitrogen gas atmosphere, so that a low resistant silicon carbide single crystal can be grown with a favorable yield.

However, in JP '297, there is no disclosure or suggestion at all about how big of a degree of stacking defects appear in the obtained silicon carbide single crystal, this being a critical defect at the time of device application. Even a description of the stacking defect itself is not found in JP '297.

Furthermore, in JP '297, as a crystal growing plane (refer to FIGs. 3(a) and 3(b) in JP '297), it is said to be most preferable to use a (11-20) plane with an angle of inclination to be 0°, or absolutely no inclination. Whereas, in the present invention, a plane inclined intentionally at an angle of 3° or more (preferably 6° or more) in the <0001> direction from the (11-20) plane is a crystal growing plane. This condition is of extremely critical significance from the view point of crystal quality of a grown crystal. This will be explained referring to experimental data in attached drawing A (Attachment A).

The horizontal axis in drawing A indicates an angle of inclination (°) from the (11-20) plane of the crystal growth plane, and the vertical axis indicates stacking defect density (cm^{-1} (per 1 cm)) in the silicon carbide single crystal obtained by crystal growth. The mark O in the drawing A indicates data in the case when it is inclined from the (11-20) plane in the <0001> direction while the mark □ indicates data in the case when it is inclined in the <1-100> direction.

As is clear from the drawing A, if the crystal growth plane is inclined in the <0001> direction, the stacking defect density sharply decreases. The stacking defect density which was about 120 pieces per cm at an angle of inclination 0° (referred to as a most favorable condition in cited JP '297) sharply decreases to several pieces per cm at the inclination angle of 10°.

On the other hand, when the crystal growth plane is inclined in the <1-100> direction, which is perpendicular to the <0001> direction, which is perpendicular to the <0001> direction, the stacking defect density increases by several times (angle of inclination 0°: about 120 cm^{-1} → angle of inclination 10°: about 380 cm^{-1}).

Thus, the stacking defect density in a silicon carbide single crystal largely depends on the direction of inclination and the angle of inclination from the (11-20) plane. Since the direction of inclination and the angle of inclination are suitably defined in the present invention, this has the effect of reducing the stacking defects by the amount of several digits. However, this excellent effect is not to such an extent that one of ordinary skill in the art can easily obtain it just by repeatedly executing the single crystal growth under various conditions.

Thus, JP '297 is silent as to the constituent features indispensable to the present invention as well as its effect, and the present invention is not the technology disclosed or suggested in JP '297.

U.S. Patent No. 5,248,385 (US '385) discloses that a silicon carbide single crystal is grown using a silicon carbide substrate of which the plane direction of the surface has an angle of inclination within 0.1 to 6 degrees from the {0001} plane ((0001) Si face or (000-1) C face).

However, the plane direction of SiC substrate surface disclosed in US '385 does not overlap the range of the present invention at all. The {0001} plane, which is a basal plane of inclination in US '385, is orthogonal to the (11-20) plane. When the range of inclination disclosed in US '385 is expressed as the inclination relative to the (11-20) plane, it is about 84 to 89.9 degrees in the <0001> direction.

Even of the disclosure of US '385 is combined with JP '297, the combination is crystallographically completely different from the range defined in the present invention. In the first place, the idea to combine US '385 and JP '297, whose crystal growth plane deviate from each other by about 90 degrees, is one that even those skilled in the art would not have come up with.

Thus, the (11-20) plane and the {0001} plane are the planes completely different from each other. Accordingly, it is quite natural that the respective surface structures and the surface physical properties differ from each other, and the types of crystal growths differ greatly when crystals are grown thereon. For instance, when crystal growth is actually carried out on the surfaces of these two crystals, they type and quantity of introduced crystal defects differ greatly.

Therefore, one skilled in the art would not combine US '385 and JP 297, and even if they can be combined, the structure and effect of the present invention cannot be obtained.

It is therefore submitted that independent claims 1 and 10, and all claims dependent thereon, are patentable over Japan No. 11-106297 or U.S. Patent No. 5,248,385 to Powell in combination with Japan No. 11-106297.

CONCLUSION

In view of the present amendment and foregoing remarks, it is submitted that the application is now in condition for allowance. It is therefore respectfully requested that the application, as amended, be allowed and passed for issue.

Respectfully submitted,

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